DESCRIPTION

METHOD OF EXTRUDING LIGHT-METAL HOLLOW MEMBER, HOLLOW EXTRUSION DIE, AND LIGHT-METAL HOLLOW MEMBER PREPARED BY EXTRUSION

Technical Field

The present invention relates to manufacturing technology of hollow members (products) made of light-metal such as aluminum by extrusion processes. Specifically, the present invention relates to extrusion technology for preparing hollow members having a variety of cross-sectional shapes from light-metal solid materials.

Background Art

Conventional methods for manufacturing a hollow member made of light-metal such as an aluminum base alloy by hot extrusion are known, such as a method shown in FIG. 5. In this method, a light-metal material 1 molded into a solid billet is fed into a container 2 of an extruder under heating; a pressure is applied from the back (from the direction shown by an arrow A in the drawing) of the light-metal material 1 by a stem 3; and the light-metal material 1 is extruded from a die opening having a predetermined cross-sectional shape to the front (to the direction shown by an arrow B in the drawing) through a couple of hollow dies 4

provided in a die-holder 9 continuing to the container 2. Thus, a product of the hollow member 5 (a rectangular tube in this drawing example) is prepared.

In this method, a hollow die such as a bridge die, a porthole die, or a spider die is used as the couple of hollow dies 4. The porthole die as an example of the hollow die is shown in FIG. 6.

The couple of hollow dies 4 has an internal die 4a positioned at the billet side and an external die 4b positioned at the hollow member 5 side. Both dies 4a and 4b are fit to each other and used in an integrated manner.

The internal die 4a includes a plurality of entry ports 6 (the example in the drawing has four entry ports, but one of them is not shown) perforated at a peripheral portion thereof and includes an internal bearing 7a (mandrel) which protrudes toward the downstream direction (the external die 4b side) in the extrusion at the central portion. The external die 4b is provided with a recessed welding chamber 8 having an approximate cross shape corresponding to the respective entry ports 6 of the internal die 4a. The welding chamber 8 has an external bearing 7b of a hole passing through the external die 4b in the axial direction at the central part. The external bearing 7b is formed into a shape so that a gap with a specified shape (a thin-walled rectangular tube in this drawing example) can be formed when

the internal bearing 7a of the internal die 4a is inserted into the external bearing 7b. Thus, the hollow member 5 having a cross-section corresponding to the gap shape can be prepared by extrusion.

The mechanism of extrusion using the couple of hollow dies 4 will be briefly described with reference to FIG. 6. The light-metal material 1 is pushed from the direction of the arrow A and is pressed into the four entry ports 6 of the external die 4b so as to be divided and to flow in the respective entry ports 6. Namely, the light-metal material 1 is divided into four parts 1a, 1b, 1c, and 1d. The divided parts 1a to 1d converge at the welding chamber 8 of the external die 4b after passing through the entry ports 6 and are welded to be unified again. The unified light-metal material 1 is extruded from a gap between the external face of the internal bearing 7a having a rectangular cross-section and the internal face of the external bearing 7b having a rectangular cross-section for receiving the internal bearing 7a with the gap in the direction of the arrow B. As a result, the hollow member (rectangular tube) 5 having a rectangular hollow cross-section corresponding to the gap shape is formed. Therefore, the resulting hollow member 5 has four edges of welding portions 5a.

Namely, since the product of the hollow member 5 prepared by this method is extruded through the processes of

dividing joining/welding which are not performed in a general method using a solid die, the hollow member 5 necessarily has the welding portions 5a corresponding to the number and position of the entry ports 6 of the couple of hollow dies 4. The metallurgical welding adhesion between the welding portions and bearing portions (non-welded portions) influences mechanical properties, such as tensile strength, proof stress, and elongation, of the hollow member, in particular, largely influences strength. Defects in the welding adhesion of the welding portions causes fracture and deformation during secondary fabrication or in use thereafter; thus, the quality may not be sufficiently guaranteed.

The extrusion using the bridge die has an advantage of that the bridge die has a life cycle longer than that of other hollow dies, but has a disadvantage of that the operation for ensuring the strength of the welding portions is difficult. For example, an aluminum base alloy can be used without causing problems in some products which are not required to have relatively high strength, such as JIS-3000 series and JIS-6000 series. However, in products which are required to have high strength, such as JIS-7000 series, it is very difficult to ensure enough strength of the welding portions because of the metallurgical properties of the aluminum base alloy. Furthermore, in the case of JIS-5000

series, it is believed in this field that the extrusion using the hollow die is impossible. Thus, even development has been abandoned.

In cooperation with such conventional conditions, no method suitable for previously evaluating the strength of the welding portions exists. Actually, the strength cannot be confirmed until a test such as a tube expansion test after the manufacturing is performed. Therefore, the lack of strength often occurs in products, and the yield ratio is low, which is a problem. When the lack of strength is found, the die shape or extruding conditions are altered according to experimental knowledge or trial and error. Such countermeasures lack in repeatability and versatility and cannot sufficiently and rapidly respond to new product shapes and prescribed properties manufactured for the first time. Furthermore, the fabricated dies are useless, which is extremely inefficient.

The present invention has been accomplished under such circumstances. It is an object of the present invention to realize and establish new extrusion technology for stably manufacturing a light-metal hollow member (product) having excellent mechanical properties by solving all the basic problems relating to strength of the welding portions in the extrusion using a hollow die such as a bridge die, and also efficiently manufacturing the product having a strength

satisfying a required level at low cost.

Disclosure of Invention

In order to achieve the object, the following configuration is adopted in the present invention.

Namely, the present invention relates to a method for extruding a light-metal material using a hollow extrusion die. The method includes a process for dividing the light-metal material once and then joining them and welding with each other; and a process for extruding the light-metal material after the joining to form in a desired cross-sectional shape through a die opening of the hollow extrusion die. In the process for extruding, the strain level applied to the light-metal material after the joining/welding is maintained at 1.8 or more and the extrusion is performed.

The term "strain level" as used herein means an average of equivalent strain level distribution generated in the light-metal material from the cross-section at the welding chamber to the product cross-section at the die outlet.

The tensile strength of the welding portions in a product can be increased to a level close to that of bearing portions by maintaining the strain level at 1.8 or more.

This method can be applied to a variety of light-metal materials. In particular, it is efficient when the metal

constituting the light-metal member is an aluminum base alloy.

The present invention relates to extrusion of a light-metal hollow member by extruding a light-metal material using a hollow extrusion die after dividing and joining/welding the light-metal material so as to have a desired cross-sectional shape. The extrusion of the light-metal material is performed by examining a correlation between the strain level applied to the light-metal material after the joining/welding and the welding strength of the welding portions of a product after the extrusion; determining a strain level corresponding to a target welding strength on the basis of the correlation as a target strain level; and maintaining the strain level applied to the light-metal material after the joining/welding at the target strain level or more.

Furthermore, the present invention relates to a hollow extrusion die used for extrusion of a light-metal hollow member having a desired cross-sectional shape by extruding a light-metal material after dividing and joining/welding. The hollow extrusion die is designed so that the extrusion can be performed while a strain level applied to the light-metal material after the joining/welding can be maintained at 1.8 or more.

Preferably, the hollow extrusion die is a bridge die, a

porthole die, or a spider die.

Furthermore, the present invention relates to a light-metal hollow member prepared by extruding a light-metal material so as to have a desired cross-sectional shape after the dividing and joining/welding of the light-metal material. The light-metal hollow member is prepared by maintaining a strain level applied to the light-metal material after the joining/welding at 1.8 or more and performing the extrusion, and the strength of the welding portions is 90% or more of that of bearing portions.

Brief Description of the Drawings

Fig. 1(a) is a perspective view of an example of a hollow die used in hollow extrusion, and FIG. 1(b) is a cross-sectional front view of the die.

FIG. 2 is a cross-sectional plan view showing changes in cross-sectional area of a molding material at the respective positions of the hollow die.

FIG. 3(a) and (b) are partial cross-sectional front views for describing the sizes of various types of the hollow dies.

FIG. 4 is a graph showing a relationship between the strain level and the welding strength on the basis of the experimental results of extrusion using a hollow die.

FIG. 5 is a schematic explanatory cross-sectional view

of a hollow-extrusion apparatus.

FIG. 6 is a partial cross-sectional perspective view of an example of a hollow die used in the hollow-extrusion apparatus.

Best Mode for Carrying Out the Invention

The principles, functions, and preferable embodiments will now be described in detail.

The inventors have conducted experiments and investigated by focusing on factors influencing the strength of the welding portions in order to overcome the aforementioned problems. As a result, it has been found that the strength is quantitatively controlled by the strain level which the light-metal material receives at a particular portion of the hollow die instead of the product temperature which is generally thought. Furthermore, the inventors have advanced the research to experimentally find that when the strain level exceeds a certain threshold, the strength of the welding portions is improved to a level close to that of the bearing portions (non-welded portions). It has been revealed that a high-quality hollow member having high weld strength can be prepared and, additionally, hollow members satisfying various requirements of strength level can be unrestrainedly manufactured by quantifying the relationship between the strain level and the shape and

configuration of the hollow die on the basis of these facts and by incorporating the results into the design of the die.

In order to clarify the influence of the strain level on the welding strength, the inventors have first investigated changes in the cross-sectional area of a billet material to know how the pressurized billet material in a container is deformed on the course of being extruded as a product through a hollow die.

FIG. 1(a) and (b) show an example of a bridge-type die 4. Fig. 2(a) to (d) show regions at each position of the die where metal (a molding material to be molded into a billet) lies, namely, typically show a cross-sectional shape of the metal. In these drawings, the peripheral outer wall and other members of the die 4 are omitted for easy viewing.

The die 4 includes an internal die 4a and an external die 4b which fit to each other. The internal die 4a includes a bridge body 41 having a cross shape and legs 42b protruding downward from four ends of the bridge body 41 in an integrated manner, and an internal bearing 7a protrudes downward from the central portion of the bridge body 41. The top face of the external die 4b includes a concave 43 for receiving the legs 42 of the internal die 4a. The concave 43 is provided with an external bearing 7b of a hole passing through the external die 4a in the axial direction at the central position of the bottom face. Relative

relationship between both bearing 7a and 7b is similar to that shown in Fig. 5 and FIG. 6.

In the die 4, as in the apparatus shown in FIG. 5, the cross-sectional shape of a light-metal material 1 is significantly changed during that the light-metal material 1 molded into a billet is fed into the container from the direction of the arrow A and then is finally extruded as a product to the direction of the arrow B. FIG. 2 shows the transition of the cross-sectional shape by focusing on a sector region S having a central angle of 45° shown in FIG. 1(a).

Specifically, FIG. 2(a), (b), (c), and (d) show the cross-sectional shapes of the light-metal material 1 at the positions of the height of the line I-I, line II-II, line III-III, and line IV-IV, respectively, shown in FIG. 1(b). In the light-metal material 1, a flowing part at the central side of the die 4 and a accumulating part which the material does not flow to be left at the outside of the flowing part are generated. In FIG. 2(a), (b), (c), and (d), the flowing part 1a of the light-metal material 1 is shown by fine mesh and the non-flowing part 1b is shown by rough mesh.

At the position of the line I-I, namely, at the position in the container above the die 4, the flowing part 1a of the light-metal material 1 fills the entire cross-sectional area. At the position of the line II-II, namely,

at the position above the legs 42 but the bridge body 41 lies, the light-metal material 1 is divided into four parts with the bridge body 41 as shown in FIG. 2(b) and the divided cross-sectional area decreases corresponding to the opening area of the bridge body 41.

Then, the divided parts pass the bridge body 41 and reach the position of the line III-III where the legs 42 lie, and are joined again and welded with each other in a welding chamber 8 formed inside the legs 42 and below the bridge body 41. Therefore, the cross-sectional shape of the metal (molding material) herein is as shown in FIG. 2(c).

At the position of the line IV-IV where both bearings 7a and 7b lie, the cross-sectional area of the metal is controlled by the size of the gap formed between the bearings 7a and 7b as shown in FIG. 2(d) and significantly decreases compared to the cross-sectional area shown in FIG. 2(c).

The inventors have investigated the transition of the cross-sectional area as referred to above and have concluded that the strain level applied to the metal during from the portion of the welding chamber 8 after the joining as shown in FIG. 2(c) to the portion after the molding as shown in FIG. 2(d) in each of the above-mentioned positions may largely influence on the welding strength. The term "strain level" as used herein means an average of equivalent strain

level distribution from the cross-section at the welding chamber to the product cross-section at the die outlet, as described above.

Consequently, the strain level is largely controlled by the cross-sectional area (Ae) of the light-metal material 1 in the welding chamber 8 and the cross-sectional area (Atp) of a product, and is also changed by the welding chamber height (H_M) and the die thickness (H_D) shown in FIG. 3(a) and (b). FIG. 3(a) shows the dimension of a bridge die or a spider die having the bridge body 41, and FIG. 3(b) shows the dimension of a porthole die having an entry port 6. In these drawings, X denotes the position of a face of the entry port, Y denotes the position of the top face of the welding chamber (top face of joining portion), and Z denotes the position of a face of the die opening.

The inventors have obtained a clear conclusion that problems in the welding strength can be fundamentally solved by quantifying relationship between these die-designing factors and the strain level and designing the die on the basis of the qualified relationship. Though a specific method for the quantification (construction of formula or function) of the designing factors and the strain level is not particularly described here, with the determination of the die shape, the strain level can be calculated by utilizing known numerical analysis such as finite element

analysis or difference calculus. Therefore, the correlation between the die-designing factors and the strain level can be relatively readily determined.

The inventors have investigated and examined the relationship among the welding strength, strain level, and their controlling factors. Then, in order to confirm the relationship can be effectively applied to actual technology, experimental extrusion of an aluminum base alloy such as 7000 series using as a test material was performed by using hollow dies of various shapes, and the strain level and the tensile strength of the resulting hollow member at each condition were measured. The following Table 1 shows experimental conditions, and Table 2 shows the results.

The extrusion in this experiment was performed under process conditions in which the extrusion temperature was 450 to 550°C, the extrusion force was 1500 to 3500 t, and the extrusion ratio was 10 to 140. The term "EP" in Table 1 is an abbreviation of entry port.

Table 1

No.	Test material (Type of Aluminum base alloy)	Die type	Die thickness H_D (mm)	Welding chamber height H_M (mm)	Product cross-sectional area Atp (mm^2)	EP area Am(mm^2)
1	JIS7N01	Bridge	145	35	1053	18188
2	JIS7N01	Entry	160	30	4005	27760
3	JIS7075	Porthole	185	35	4475	37468
4	JIS7003	Spider	50	10	1906	15768
5	JIS7N01	Bridge	30	20	255	9488
6	JIS7003	Spider	30	8	255	9488
7	JIS7N01	Porthole	30	20	255	5251
8	JIS7075	Bridge	30	8	255	5251
9	JIS7N01	Bridge	100	25	1562	33970
10	JIS7075	Porthole	100	20	1102	29517
11	JIS7N01	Bridge	60	10	725	10378

Table 2

No.	Strain level	Tensile strength at welding portion / tensile strength at bearing portion
1	1.59	Poor
2	0.75	Poor
3	0.87	Poor
4	0.90	Poor
5	3.22	Good
6	2.37	Good
7	2.64	Good
8	1.83	Good
9	2.41	Good
10	3.15	Good
11	1.78	Poor

Table 2 shows that the tensile strength ratios in all the test materials having a strain level of 1.8 or more were 90% or more, unlike the test materials having a strain level less than 1.8. It is observed that the welding strength at

the welding portion does not highly different from that of the bearing portion. Therefore, excellent hollow members having the welding portions with high strength can be stably manufactured by that a threshold of the strain level is determined at 1.8 and the extrusion is performed while maintaining the strain level at the threshold or more.

FIG. 4 is a graph showing the relationship between the strain level and the welding strength when the number of the test materials are increased by adding the results of further experiments in addition to the above results. In the drawing, the solid line parallel to X-axis positioned at a tensile strength ratio between the welding portion and the bearing portion of 100% shows the tensile strength of the bearing portion (non-welding portion), and the dotted curve line shows the tensile strength of the welding portion.

With referred to the drawing, there is a clear positive correlation between the strain level and the welding strength, and when the strain level is 1.8 or more, as was expected, the strength ratio is 90% or more. Thus, it is observed that the welding portion is also excellent in strength. Furthermore, in particular, it is observed that the strain level in the range of 2.4 or more can generate the welding portion having very high strength such as a strength ratio of 95% or more, and that a hollow member of improved high quality being almost equal to strength of a

bearing material can be provided. Namely, these experimental results show the strain level must be maintained at 1.8 or more during the extrusion in order to prepare the light-metal hollow member having a tensile strength ratio of 90% or more, in particular, when the strain level is maintained at 2.4 or more during the extrusion, the light-metal hollow member having high strength characteristics can be prepared.

As described above, the light-metal hollow member having sufficient welding strength can be stably prepared by examining the correlation between the strain level and the welding strength; determining a strain level corresponding to a target welding strength on the basis of the resulting correlation and using the strain level as a target strain level; designing a hollow extrusion die so that the strain level applied to the light-metal hollow material is maintained at the target strain level or more during the extrusion after the joining/welding; and performing the extrusion using the die.

In the above-mentioned embodiment, the beneficial effects of the present invention was verified by using aluminum base alloys. The present invention can be applied to the extrusion of other light-metals (including alloys), for example, tin, antimony, titanium, magnesium, and beryllium, to obtain similar effects.